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HEALTH EFFECTS OF ELECTRIC FIELDS AND INTERCONNECTORS

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This paper details the outcomes of various studies that have been conducted into the health effects of electric fields and interconnectors.

SUMMARY OF KEY POINTS

- Electric fields arise from electric charges, are measured in Volts per meter (V/m). Magnetic fields arise from the motion of electric charges. Both types of field are strongest close to the source and decrease with distance

- World Health Organization (WHO)established the International Electromagnetic Fields Project to investigate the potential health risks associated with technologies emitting EMF

- The Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public.

- The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and other health effects is weak.

- The United Kingdom Childhood Cancer Study (UKCCS) states in relation to their own study that there is “no evidence that exposure to magnetic fields associated with the electricity supply in the UK increases the risk for childhood leukaemia, cancers of the nervous system, or any other childhood cancer”

- International Commission on Non-Ionizing Radiation Protection (ICNIRP) have produced the following levels as guidance in relation to public exposure;

  (1) 100 Microteslas for magnetic fields
  (2) 5000 Volts per meter for electric fields

- Northern Ireland Electricity and EirGrid announced a new North-South interconnector, which will further connect the electricity systems of Northern Ireland and the Republic of Ireland.

- Overhead line and underground cable alternatives are proven solutions for the transmission of electricity.

CONTENTS

INTRODUCTION

This paper provides an overview of the research that has been conducted into the health effects of electric fields and interconnectors. The paper highlights the differences between electric and magnetic fields and there various impacts on human health.

Below is a list of the abbreviations and terms that are used throughout this paper;

- CCRG – Childhood Cancer Research Group
- EMF - Electric magnetic Field
- Epidemiology – study of factors affecting the health and illness of a population
- HPA – Health Protection Agency
- HVAC – High voltage Alternating Current
- HVDC – High voltage Direct current
- IARC – International Agency for Research on Cancer
- ICNIRP – International Commission on Non-Ionizing Radiation Protection
- Magnetic Field Units – Tesla (T), Millitesla (mT) and Microtesla (μT)
- WHO – World Health Organization

WORLD HEALTH ORGANIZATION: WHAT ARE ELECTROMAGNETIC FIELDS?

The World Health Organization (WHO) states that electric fields are created by differences in voltage: the higher the voltage, the stronger the field. Magnetic fields are created when electric current flows: the greater the current, the stronger the magnetic field. An electric field will exist even when there is no current flowing. If current does flow, the strength of the magnetic field will vary with power consumption but the electric field strength will be constant[1].

Electromagnetic fields are present everywhere in our environment but are invisible to the human eye. The table below summarises the characterises of electric and magnetic fields[2].

Electric Fields	**Magnetic Fields**
Arise from Voltage	Arise form current flows
Their strength is measured in Volts per meter (V/m)	Their strength is measured in amperes per meter (A/m)
An electric field can be present even when a device is switched off	Magnetic fields exist as soon as a device is switched on
Field strength decreases with distance from the source	Field strength decreases with distance from the source
Most building materials shield electric fields to some extent	Magnetic fields are not weakened by most materials

ELECTROMAGNETIC FIELDS AND PUBLIC SAFETY

The WHO states that whenever electricity flows, both electric and magnetic fields exist close to the lines that carry electricity. Since the late 1970s, questions have

[1] World Health Organization, http://www.who.int/peh-emf/about/WhatisEMF/en/
[2] World Health Organization, http://www.who.int/peh-emf/about/WhatisEMF/en/

been raised, as to whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences[3].

In 1996, WHO established the International Electromagnetic Fields Project to investigate the potential health risks associated with technologies emitting EMF; and a WHO task group in 2007 concluded a review of the health implications of ELF fields. The information that follows is based on the findings of this task group[4].

Electric fields arise from electric charges, are measured in Volts per meter (V/m) and are shielded by common materials, such as wood and metal. Magnetic fields arise from the motion of electric charges (a current); the unit of measure for magnetic fields can be any of the following units - tesla (T), millitesla (mT) or microtesla (µT). These fields are not shielded by most common materials, and pass easily through them. Both types of field are strongest close to the source and decrease with distance[5].

Underneath power lines, magnetic fields can be approximately 20µT (microtesla) and electric fields can be several thousand volts per meter. However, average residential power-frequency magnetic fields in homes are much lower – about 0.07µT (microtesla) in Europe. The average values of the electric field in the home are up to several tens of volts per metre[6].

TASK GROUP EVALUATION

This Task Group, established by the WHO, was comprised of scientific experts to assess any health risks that might exist from exposure to ELF electric and magnetic fields in the frequency range >0 to 100,000 Hz (100 kHz)[7].

The Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus, the report highlights the effects of exposure to **ELF magnetic fields**[8]. The effects can be both short and long term and are described as follows;

Short term effects – acute exposure at high levels (above 100µT) can be seen to have biological effects. External ELF magnetic fields induce electric fields and currents in the body which, at very high field strengths, cause nerve and muscle stimulation and changes in the central nervous system[9].

Potential long term effects – in 2002, the International Agency for Research on Cancer (IARC)[10] stated that ELF magnetic fields are "possibly carcinogenic to humans". This finding was based on analyses of epidemiological (study of factors affecting the health and illness of a population) studies highlighting a pattern of a two-fold increase in childhood leukaemia. The Task Group found an associated with cancer and average exposure to a residential power-frequency magnetic field above 0.3 to 0.4µT. The World Health Organization Task Group concluded that additional studies since then do not alter the status of this finding[11].

[3] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[4] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[5] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[6] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[7] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[8] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[9] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[10] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[11] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html

The World Health Organization states that childhood leukaemia is a comparatively rare disease with the total annual number of new cases estimated to be 49,000 worldwide in 2000. Indeed, average magnetic field exposures above 0.3μT in homes are rare: it is estimated that between 1% and 4% of children live in such conditions. Thus, the number of childhood leukaemia cases worldwide that might be attributed to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000; representing 0.2% to 4.95% of the total incidence for that year. Therefore, when considered in a global context, the impact on public health of ELF and EMF exposure would be limited[12].

OTHER HEALTH EFFECTS

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include;

- other childhood cancers
- cancers in adults
- depression
- suicide
- cardiovascular disorders
- reproductive dysfunction
- developmental disorders
- immunological modification
- neurobehavioural effects
- neurodegenerative disease

The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than childhood leukaemia. In some instances (for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them[13].

INTERNATIONAL GUIDELINES

Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines. At present, these bodies consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering the exposure limits[14].

WHO GUIDANCE

For high-level, short -term exposure to EMF, adverse health effects have been scientifically established. International exposure guidelines designed to protect workers and the public from these effects should be adopted by policy makers. EMF protection programs should include exposure measurements from sources where exposures might be expected to exceed limit values[15].

[12] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[13] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[14] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[15] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html

Under WHO guidelines the following recommendations are given regarding exposure to ELF magnetic fields[16];

- Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda
- Establishing effective communication programmes, including improving coordination and consultation among industry, local government, and citizens in the planning process for ELF, EMF-emitting facilities
- When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored.

ENERGY NETWORKS ASSOCIATION: POTENTIAL HEALTH EFFECTS

The Energy Networks Association states that although attention has focused on childhood cancer and leukaemia in relation to exposure to EMF; other diseases including adult cancers, heart disease, Alzheimer's disease, incidence of suicide, miscarriage and depression have been investigated.

Epidemiology studies first raised concerns about EMFs in 1979. The strength of epidemiology is that it looks directly at human populations. However, all it can ever do is observe statistical associations. It can never completely eliminate all the many factors that determine whether people develop diseases or not, and so it can never prove whether a particular disease is caused by EMFs or not[17].

According to this report, approximately 20 epidemiological studies have now been carried out to look just at a possible link between childhood leukaemia and EMFs. Some of these studies have not found association with magnetic fields, but some have found other associations[18]. The Energy Networks Association states that in relation to electric fields, the position is clearer: there is very little evidence suggesting they are a cause of childhood cancer.

The two largest epidemiology studies of childhood cancer and EMFs that have been carried out so far both come from the UK[19].

The United Kingdom Childhood Cancer Study (UKCCS) was conducted during the 1990s; investigating a number of suggested causes of childhood cancer including EMFs. It was a large study, with over 2000 cases of cancer in total investigated and every case occurring in the UK over a four-year period. In 1999, the UKCCS published its first report in relation to magnetic field exposure, and concluded[20],

[16] World Health Organization, http://www.who.int/mediacentre/factsheets/fs322/en/print.html
[17] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[18] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[19] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[20] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf

"This study provides no evidence that exposure to magnetic fields associated with the electricity supply in the UK increases the risk for childhood leukaemia, cancers of the nervous system, or any other childhood cancer"

Subsequent UKCCS paper in 2000 and 2002 looked at children living close to power lines and at electric fields, in both cases reporting finding "no evidence" or "no support".

The Childhood Cancer Research Group (CCRG) looked at 33,000 cases of childhood cancer from 1962 to 1995 and the distance of their address at birth from the nearest 275 kV and 400 kV power line. The research found an association between childhood leukaemia and these power lines (1.7 fold increase close to the lines). But this association extended too far (600m) from the lines to be caused by magnetic fields. The paper concludes[21]:

"We have no satisfactory explanation for our results in terms of causation by magnetic fields or association with other factors"

ENERGY NETWORKS ASSOCIATION: ELECTRIC AND MAGNETIC FIELDS

The Energy Networks Association states that over £300 million has been spent investigating any link between exposure to EMF and ill-health around the world; research is continuing, however, the balance of scientific evidence to date suggests a negative correlation between the two factors[22].

The Government sets guidelines for exposures to EMFs in the UK on advice from the Health Protection Agency (HPA). In 2004 the UK decided in principle to adopt the guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These guidelines also form the basis of a European Union Recommendation on public exposure and a Directive on occupational exposure[23].

The ICNIRP reference levels for the public are:

(1) 100 Microteslas for magnetic fields
(2) 5000 Volts per meter for electric fields

Occupational reference levels are higher at 500 Microteslas and 10,000 volts per meter.

The above mentioned magnetic and electric fields levels are the levels above which more investigation is needed; the permitted levels of exposure are somewhat higher. They are designed to ensure that EMFs do not interfere with nerves in the human body, but were set after examining all the evidence, including the evidence on cancer. The Energy Networks Association stated that the electricity industry's policy is to follow independent exposure guidelines. The majority of exposures from the UK

[21] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[22] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[23] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf

electricity system (and all exposures in homes) already comply with ICNIRP guidelines[24].

OUTSIDE THE HOME

All overhead power lines, outside homes produce fields. The fields are usually at the most intense directly under the lines and then fall rapidly with distance. For small lines on wooden poles, the fields generally fall away over a few tens of meters. For large lines on steel pylons, the distance is slightly greater. Fields vary greatly between lines and a line typically produces fields much less than the maximum it is capable of[25].

UNDERGROUND CABLES

High-voltage underground cables can produce higher magnetic fields directly above them than an overhead line would produce at ground level. This is because the physical distance from the underground cable is smaller. The field falls more rapidly with distance to the sides, and they produce no external electric field. Such cables are not normally located beneath buildings[26].

THE INTERNATIONAL EMF PROJECT

WHO's International EMF Project provides a unique opportunity to encourage the establishment of exposure limits and control measures in order to provide the same or similar level of health protection internationally. The key risk management objectives of the Project are to[27];

(1) Facilitate the development of internationally acceptable standards for EMF exposure
(2) Provide information on the management of EMF protection programs for national and other authorities, including monographs on EMF risk perception, communication and management
(3) Provide advice to national authorities, other institutions, the general public and workers, about any hazards resulting from EMF exposure and any needed mitigation measures

FRAMEWORK FOR DEVELOPING STANDARDS

The overall purpose of this framework is to provide advice on how to develop science-based exposure limits that will protect the health of the public and workers from EMF exposure. This Framework is intended for national advisory and/or regulatory bodies that are developing new standards for EMF, reviewing the basis of their standards, or reconsidering specific quantitative values such as reference levels and safety factors[28].

[24] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[25] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[26] Energy Networks Association, http://www.nie.co.uk/interconnector/docs/electricandmagneticfields.pdf
[27] World Health Organization, http://www.who.int/peh-emf/project/IAC%20progress%20report_final.pdf
[28] World Health Organization, http://www.who.int/peh-emf/project/IAC%20progress%20report_final.pdf

MODEL LEGISLATION

EMF Project has developed a Model Act and Model Regulation that provide the legal framework to provide this protection. The Model Legislation follows the widely accepted practice among law-makers of setting out an enabling Act which permits the responsible Minister to subsequently issue Regulations, Statutory Orders or Ordinances, as appropriate, to deal with specific areas of concern[29].

An important aspect of this legislation is that it recommends the use of international standards that limits EMF exposure of people and international standards that limit the emissions of EMF form devices[30].

INTERCONNECTORS: NATIONAL GRID

In May 2007, National Grid announced that it would be proceeding with the BritNed interconnector between the UK and the Netherlands. This is a joint venture with **Dutch TSO Tenne T** and is expected to be completed by 2010. In 2001 National Grid and Eirgrid (the Republic of Ireland's grid operator) completed a feasibility study into the construction of a 500MW interconnector between Ireland and Wales. National Grid remains interested in this project, which has recently been endorsed by the Irish Government.

National Grid's domestic transmission system covering England and Wales is linked by an interconnector to the transmission system of France. Although there is sufficient generation in the British transmission system (which includes the Scottish transmission network operated under licence by the Scottish transmission owners) to meet demand, by linking to another country's transmission system, the National Grid can facilitate competition in the wholesale electricity market covering England, Scotland and Wales.

NORTHERN IRELAND ELECTRICITY

EirGrid and Northern Ireland Electricity announced a new North-South interconnector, which will further connect the electricity systems of Northern Ireland and the Republic of Ireland. Northern Ireland Electricity states that the Tyrone to Cavan interconnector will help reduce network operating costs and strengthen electricity supply on both power systems. It will also support greater competition in the electricity market and facilitate more electricity generated from renewable sources being brought onto the system[31].

NORTHERN IRELAND AND THE REPUBLIC OF IRELAND OVERHEAD AND UNDERGROUND ENERGY TRANSMISSION OPTIONS

Two projects have been proposed to develop the electricity transmission infrastructure of the island of Ireland[32];

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[29] World Health Organization, http://www.who.int/peh-emf/project/IAC%20progress%20report_final.pdf
[30] World Health Organization, http://www.who.int/peh-emf/project/IAC%20progress%20report_final.pdf
[31] Northern Ireland Electricity, http://www.nie.co.uk/customerinformation/networkprojects.htm
[32] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf

(1) EirGrid and Northern Ireland Electricity (NIE) have proposed a new 80km 400kV electricity connection between the Republic of Ireland and Northern Ireland; the Cavan – Tyrone 400kV Project , and
(2) EirGrid has proposed a further 60km, 400kV development to the transmission network north of Dublin; the Meath – Cavan 400kV Project

There are several technical alternatives by which these two projects could possibly be achieved, the principal technologies being: overhead or underground connections or a combination of both; and High Voltage Alternating Current (HVAC) or High Voltage Direct Current (HVDC) technology[33].

Overhead line and underground cable alternatives are proven solutions for the transmission of electricity. However, while the HVAC partial under-grounding of the route is a possibility that can be considered, HVAC underground cable has not been used anywhere to date for the route lengths associated with the two projects[34].

Both HVAC and HVDC alternatives are also proven solutions for the transmission of electricity[35].

COST OF OVERHEAD AND UNDERGROUND INTERCONNECTORS

Preliminary costs have been prepared based on information used for the Beauly – Denny 400kV overhead line in Scotland. These costs have been adapted for the Cavan-Tyrone and Meath-Cavan 400kV projects by Northern Ireland Electricity and show that HVAC overhead line has the lower capital and lifetime costs with capital costs of about £0.7m/km (€0.9m/km). HVAC underground cable would be about 9 times more expensive than an HVAC overhead line implementation[36].

The main technical differences between overhead and underground cables are summarised below;[37]

Reliability and availability – the average repair times of cables are much higher than those for overhead lines, resulting in higher than average unavailability of cable circuits, length for length[38].

[33] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf
[34] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf
[35] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf
[36] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf
[37] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf
[38] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf

Power – currents flowing in cables tend to be higher than in overhead lines as a result of cable charging currents, however, generally cable losses are still lower than overhead line losses because of their lower resistances[39].

Service Experience – 103.552km of overhead line are in service in continental Europe compared with 907km of underground cable. HVAC underground cable has not been used to date for long distance HVAC transmission. The longest application of a 500kV HVAC XLPE cable interconnection is in Japan where it is used for the supply of the metropolitan area of Tokyo[40].

Reactive Power – The capacitance added to the system by underground cable is considerably higher than that from overhead lines. This capacitance requires extra compensation at terminating substations and possibly the introduction of two **compensation substations** along the route, one on the Cavan-Tyrone section of the route and the other on the Meath-Cavan section of the route[41].

Overvoltages – The capacitance added to the system by underground cable also has the effect of lowering the frequencies at which the system resonates. Without more costly designs, equipment damage can result, particularly if there are high levels of underground cable and low short circuit levels[42].

[39] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf

[40] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf

[41] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf

[42] Northern Ireland Electricity, http://www.nie.co.uk/interconnector/docs/pb%20Power%20summary%20report%20on%20underground-final%2011%20(2_.pdf